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Status Report

THEORY OF CERTAIN ENERGY SURFACES AND BRILLOUIN ZONES

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ABSTRACT

Part I Brillouin Zones.—The influence of a plane with weak Fourier coefficient on the energy surfaces near a plane with strong coefficient is studied by calculating numerically through a simple example in two and three dimensions.

Part II Photographic Latent Image.—The influence of grain size on the low-intensity reciprocity failure is studied. With surface development no influence is detectable, but with internal development a dependence is indicated.

Experiments to obtain isodense sequence loops in the same intensity range have been successful but require slight corrections to the equipment which was built for this purpose.

OBJECTIVES

Part I.—The theoretical study of the energy surfaces of solids in connection with Brillouin zones.

Part II.—The experimental study of certain features of photographic latent-image formation which may contribute to its improved understanding.

INTRODUCTION

This project covers two independent parts: the theory of energy surfaces and Brillouin zones and the work on the photographic latent image.

The work of Part I (Brillouin zones) is done by Mr. G. B. Spence. The problems encountered are very complex, and even upon reduction to a relatively simple form require time-consuming approximations and planimetry. An encouraging discussion of the work with Professor W. Kohn during his visit here last June is acknowledged. It is expected that this part will be in a sufficiently rounded form for a technical report in a few months.

The work on Part II (photographic latent image) was reported in two papers at the March meeting of the American Physical Society at Baltimore, Maryland, by R. L. Martin, J. H. Enns, and E. Katz. At this meeting we had the opportunity to discuss our work with Dr. J. Webb of the Kodak Research Laboratory who gave us helpful advice.

Dr. J. W. Mitchell, from Bristol, England, visited Ann Arbor on March 19-21 and again on March 31, 1955, on his lecture tour through the United States sponsored by ARDC. He delivered two very interesting lectures at The University of Michigan and discussed at great length with us the results of his work and its relation to ours. This discussion proved very stimulating. Dr. Mitchell's attitude tended more than previously to be phenomenological, which was particularly valuable.

Also, grateful mention should be made of the continued kind cooperation received from the Kodak Research Laboratory. Dr. J. A. Leermakers furnished us with emulsions especially prepared for our work on grain-size effects.

PART I

THEORY OF CERTAIN ENERGY SURFACES AND BRILLOUIN ZONES

Certain problems in the Brillouin-zone theory of metals can be investigated in the limiting case when only a few of the coefficients of the Fourier expansion of the periodic crystal potential are nonzero. This has led to an investigation of the Schrödinger equation

$$\frac{d^2\psi}{dx^2} + (4\epsilon - 8v_1 \cos 2x - 8v_2 \cos 4x)\,\psi = 0.$$

Ince's solution giving the dependence of the energy ϵ on the wave vector k in the form of a power series in $v_1{}^i v_2{}^j$ has been extended to the fifth order. From the analytical series, two numerical examples have been computed, the first for $v_1 = 0$, $v_2 = .3$, and the second for $v_1 = .03$, $v_2 = .3$.

Two- and three-dimensional problems can be constructed by a superposition of one-dimensional problems along different directions. In order to determine the significance of certain degeneracies in the energy at Brillouin-zone boundaries, the two-dimensional energy contours are being computed and plotted graphically for the first numerical example. Another problem in zone theory is to determine the significance of a weak coefficient ($v_1 = .03$) compared to a stronger coefficient ($v_2 = .3$). This is being investigated both by plotting the two-dimensional energy contours for the second numerical example and by determining graphically the density-of-states function for these contours. This work is being extended by determining the density-of-states function for the corresponding three-dimensional problem. The density-of-states functions are being determined with sufficient accuracy to show the considerable complexity introduced into their shape by the singularities in the energy function.

When this work is completed, we plan to investigate a few related problems necessary to complete this study of degeneracies on Brillouin-zone boundaries and the significance of weak coefficients in the crystal potential.

PART II

PHOTOGRAPHIC LATENT IMAGE

Work has been done along two lines:

Mr. R. L. Martin, assisted by Mr. S. K. Derby, has worked on the very-low-intensity reciprocity failure as a function of grain size.

Dr. J. H. Enns has worked on the "sequence loops."

A. WORK ON THE VERY-LOW-INTENSITY RECIPROCITY FAILURE

Work was devoted to the measurement of low-intensity reciprocity failure for pure silver bromide emulsions of maximum sulfur sensitization.

Preliminary work during the beginning of the year indicated the following, for development with surface developer:

1. The low-intensity part of the reciprocity-failure curve (log It versus log I for constant D) has a characteristic kink at exposures of the order of about 100 minutes so that the slope for lower intensities is several times as great as the slope for intermediate intensities.

2. The slopes of the curves for the several emulsions of differing average grain size differ less than the experimental errors if appropriate densities are compared.

3. The lack of constant reproducibility in these experiments was probably mostly due to differing history of the emulsions before exposure.

After presenting these preliminary results at the Baltimore meeting of the American Physical Society, the work was repeated, using more care in history of the emulsions before and after exposure along with some improvements in the control of the temperature and humidity during the experiment. We then reached the same conclusions with much better reproducibility. Then the same set of emulsions was used to measure the reciprocity failure, now for the internal latent image. We don't have under control as yet all the factors which affect the reproducibility. However, the following preliminary conclusions can be drawn.

1. The reciprocity-failure curves for the internal image do not have the kink observed with the surface development.

2. The slopes of the curves increase with increasing density.

3. For given density, the slope increases with the average grain size of the emulsion.

The experiments were done at 100°F in order to assure constant temperature during the summer months. Measurements at lower temperatures are intended, by which undesirable changes of the emulsion with time will be diminished. Also, measurements of the same type are planned for pure silver bromide emulsions of minimum sulfur sensitization, approximating primitive emulsions.

B. WORK ON THE "SEQUENCE-LOOP" EXPERIMENTS

The nature and purpose of the sequence experiment were stated on page 5 of the previous project-status report, dated December 1954. The design and shop work of the final instrument for administering the exposures required for isodense sequence loops were completed early in March of this year. A paper describing the experiment and the instrument was presented in March at the Baltimore meeting of the American Physical Society. This paper included some of the first sequence-exposure data taken with the instrument.

Briefly, the instrument is designed to record automatically sequence-exposure data on a standard 4- by 10-in. plate. A sequence-exposure run will record up to 384 4- by 5-mm rectangles uniformly exposed for densitometry measurements. Provision is also made to record plate calibration data. At present, one exposure run requires 33 hours, following which a plate is usually stored for an equal period before developing. The duration of an exposure is proportional to the high-to-low light-intensity ratio. Initially, this ratio was chosen to be 100. With relatively minor changes, lower as well as higher intensity ratios can be used.

Since the completion of the instrument in March, it has been in almost continuous operation. Sequence-exposure data have been obtained for three different types of emulsions. Up to the present, such data have been analyzed only to the extent of checking reproducibility, studying the inherent properties of the instrument, how to correct for errors, and finally determining the corrections necessary to account for nonuniformity in an emulsion. The low-intensity reciprocity-failure values obtained as a by-product from these data have been in close agreement with the values from the reciprocimeter experiment.

For the immediate future, the program is to apply the above corrections to the photographic data already available and continue the analysis to the point of deriving information on the latent-image formation relevant to the theory. This probably will require taking additional photographic data for other emulsions, making changes in the exposure, temperature, development conditions, etc., and analyzing the new data in the above manner.